

Title: The effect of morphology and process conditions on the performance of Cu based electrodes in electrochemical CO₂ reduction

Abstract:

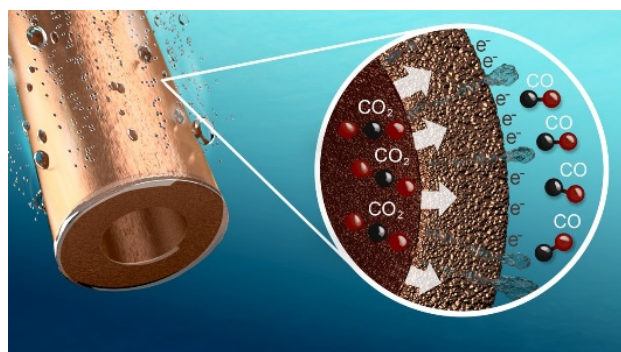
Recep Kas¹, Ruud Kortlever², Nieck E. Benes³, Marc T.M. Koper² and Guido Mul¹

¹PhotoCatalytic Synthesis Group, MESA+ Institute for Nanotechnology, Faculty of Science and Technology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands.

²Leiden Institute of Chemistry, Leiden University, Einsteinweg 55, P.O. Box 9502, 2300 RA Leiden, The Netherlands

³Inorganic Membranes Group, Faculty of Science and Technology, MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

Electrochemistry is a technology that sees a revival in the number of applications and publications, because of fluctuations in renewable electricity production, with periods of over-capacity, resulting in low, or even negative electricity prices. To utilize this electricity the PCS group of the University of Twente conducts research to effectively convert CO₂. Three aspects of Cu catalyzed CO₂ reduction will be discussed during the presentation. i) The structure and oxidation state of Cu₂O derived Cu electrodes when active in CO₂ reduction will be addressed¹. It will be shown that the selectivity of CO₂ reduction largely depends on the thickness of the parent Cu₂O film, rather than on the initial crystal orientation. It will also be shown by online mass spectroscopy studies combined with X-ray diffraction and Raman data that reduction of the Cu₂O films in the presence of CO₂, generating a nanoparticulate Cu morphology, occurs prior to the production of hydrogen, CO, and hydrocarbons. ii) The effect of process conditions on the electrocatalytic selectivity and stability will be discussed. An identical electrode covered with copper nanoparticles can yield either predominantly ethylene or methane. Methane is favored at high KHCO₃ electrolyte concentration (0.5 M), and low CO₂ pressure, whereas ethylene is formed predominantly at low KHCO₃ electrolyte concentration (0.1 M) and high CO₂ pressure (9 atm)². These observations will be explained on the basis of differences in pH near the electrode surface. iii) A means to prevent mass transport limitations in electrocatalytic conversion of CO₂ to CO will be demonstrated³. The cartoon highlights a novel electrode design in which gas is purged through a porous wall of a sintered metal tube (hollow fiber). The excellent results obtained by using such morphology will be discussed.



1. R. Kas, R. Kortlever, A. Milbrat, M. T. M. Koper, G. Mul and J. Baltrusaitis, *Phys. Chem. Chem. Phys.*, 2014, **16**, 12194-12201.
2. R. Kas, R. Kortlever, H. Yilmaz, M. T. M. Koper and G. Mul, *ChemElectroChem*, 2015, **2**, 354-358.
3. R. Kas, K. K. Hummadi, R. Kortlever, P. de Wit, A. Milbrat, M. W. J. Luiten-Olieman, N. E. Benes, M. T. M. Koper and G. Mul, *Nat. Commun.*, 2016, **7**, 7.

Bio:

Guido Mul obtained his masters degree in chemistry with specialization in heterogeneous catalysis (Prof. Geus) from Utrecht University in 1992. He received his PhD in 1997 from the Delft University of Technology on the in situ DRIFT analysis of catalytic oxidation of (diesel) soot, research conducted under supervision of Prof. Jacob Moulijn. After a Post-Doc position at SRI-International (Stanford Research Institute) in California, USA (1997-1999), he was awarded a fellowship of the KNAW (Royal Netherlands Academy of Arts and Sciences). This allowed him to determine the mechanism of oxidation reactions, using an integrated approach based on Infrared and Raman spectroscopies and transient kinetics, again at the Delft University of Technology (TUD). He was appointed associate professor at TU Delft in 2007, where his research continued with developing/evaluating spectroscopies (ATR, Raman) for analyses of liquid phase (photo)catalytic processes. He was appointed full professor to conduct research in the field of 'Photocatalytic Synthesis' at the University of Twente in 2010, with research activities in photocatalysis and electrocatalysis for environmental applications, including water and air decontamination, and CO₂ conversion to store renewable electricity in the form of fuel-type molecules. Furthermore, development and evaluation of photo- and electrocatalytic processes for conversion of methane, are part of his activities. Research is focused on studying catalyst structure activity correlations by among others Infrared and Raman spectroscopy, as well as optimization of process conditions and reactors for photo- or electrochemical conversions.